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ECOTONE Manual

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Tamara Hochstrasser and Debra Peters

USDA-ARS Jornada Experimental Range
Box 30003, MSC 3 JER
New Mexico State University
Las Cruces, NM 88003

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ABSTRACT

The U.S. Department of Defense is responsible for managing over 25 million acres of land and uses a variety of programs, tools, and procedures to periodically assess and evaluate land condition. One tool, the ECOTONE model, was set up to simulate vegetation recovery from military disturbances on Fort Bliss, Texas, as a conceptual structure to prioritize the research efforts in land management. This report provides the first published documentation of the structure and function of ECOTONE. The model consists of processes—dispersal, establishment, growth, etc.—that flow into each other and are themselves influenced by disturbances, resulting in varying rates of plant mortality.

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PREFACE

This study was conducted for the Office of the Directorate of Environmental Programs (DAIM), Assistant Chief of Staff (Installation Management) (ACS[IM]) under project 622720896, "Environmental Quality Technology," Work Unit CNN-T081. The technical monitor was Dr. Vic Diersing, DAIM-ED-N.

The Construction Engineering Research Laboratory (CERL) Principal Investigator was Dr. Jeffrey S. Fehmi. The managers at Fort Bliss were Kevin vonFinger and Brett Russell. The work was performed under contract by Debra P.C. Peters and Tamara Hochstrasser in association with New Mexico State University and USDA-ARS Jornada Experimental Range. Mr. Stephen Hodapp is Chief, CEERD-CN-N, and Dr. John T. Bandy is Chief, CEERD-CN. The associated Technical Director was Dr. William D. Severinghaus, CEERD-CV-T. The Director of CERL is Dr. Alan W. Moore.

The ECOTONE model was developed by Debra Peters between 1993 and 2003. If you have further questions, contact her at USDA-ARS-Jornada Experimental Range, Box 30003, MSC 3 JER, New Mexico State University, Las Cruces, NM 88003 (Email: debpeter@nmsu.edu).

CERL is an element of the U.S. Army Engineer Research and Development Center (ERDC), U.S. Army Corps of Engineers. The Commander and Executive Director of ERDC is COL John Morris III, EN and the Director of ERDC is Dr. James R. Houston.

ECOTONE MANUAL

TAMARA HOCHSTRASSER AND DEBRA PETERS

1 INTRODUCTION

The U.S. Department of Defense is responsible for managing over 25 million acres of land and uses a variety of programs, tools, and procedures to periodically assess and evaluate land condition. The ECOTONE model was used to simulate vegetation recovery from military disturbances on Fort Bliss, Texas (Hochstrasser et al., in prep.). This reports provides the first published documentation of the structure and function of ECOTONE.

2 USING ECOTONE

ECOTONE is a spatially interactive individual-plant-based gap dynamics simulation model that simulates the recruitment, growth, and mortality of individual plants on a small plot (Goslee et al. 2001, Peters 2002) (Fig. 1). Recruitment and mortality have stochastic elements, and growth is determined by competition for below-ground resources (currently water). Plot size is determined by the resource space associated with a full-size individual of the dominant species, and it typically ranges from 0.5 to 2 m^2 in desert grasslands and shrublands. ECOTONE can be run either with a spatially explicit connection between plots (dependent landscape, ltype = 2 – runs.in) or with no spatially explicit connection between plots (independent landscape, ltype = 1 – runs.in). If ECOTONE is run with a spatially explicit connection between plots, the seed availability in any given plot depends on seed dispersal to that plot. Input parameters include plant life history traits as well as environmental variables (daily precipitation and temperature, soil texture, and disturbance characteristics). A daily time step soilwater model [SOILWAT (Parton 1978)] has been incorporated into ECOTONE to represent seasonal variation in plant growth as a result of daily temperature and water availability by depth in the soil profile. Growth and mortality of plants occurs on a yearly time step. Output includes species composition, plant density, above- and below-ground biomass and production by species, size and age distributions, and mortality statistics.

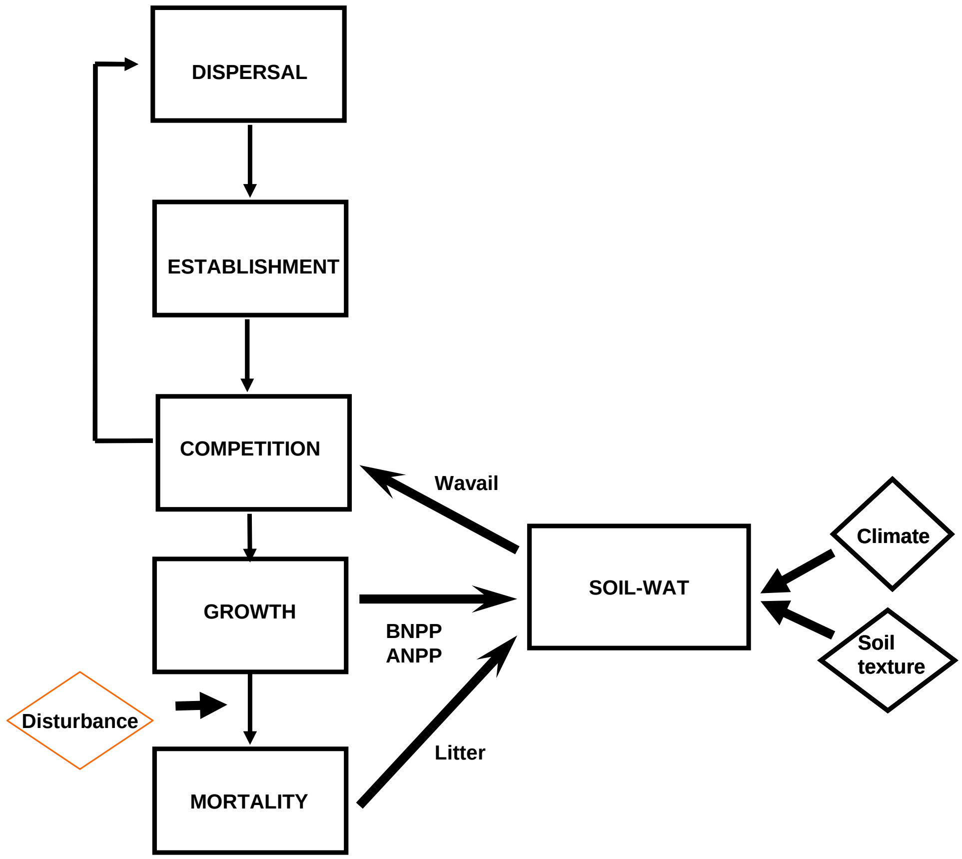

Figure 1. Flow diagram of ECOTONE.

Two sets of ECOTONE input files—the source code and the ECOTONE executable file—are available on the appended CD. Before using ECOTONE, read the README.doc file containing the instructions on how to run the model. The input data sets are the inputs used for the work conducted for a presentation at the Ecological Society of America meeting in 2003 (Hochstrasser et al., in prep.). The runs are without disturbances and on a single plot, which allows the user to follow the growth of individual plants.

If you want to use the model with trampling disturbances, define the year (during the run, i.e. 1 – end of simulation run) in which you want to apply the disturbance (distyr in dist_tramp.in), the disturbance width (dtwi in dist_tramp.in), the track width (trackwi in dist_tramp.in), and the number of passes (n_passes in dist_tramp.in) (Fig. 2). When you define how much pressure the vehicle or person is going to apply to the vegetation (pressure in dist_tramp.in), keep in mind that what is important for the amount of damage to the plant is the relative pressure (i.e. the amount of pressure applied relative to

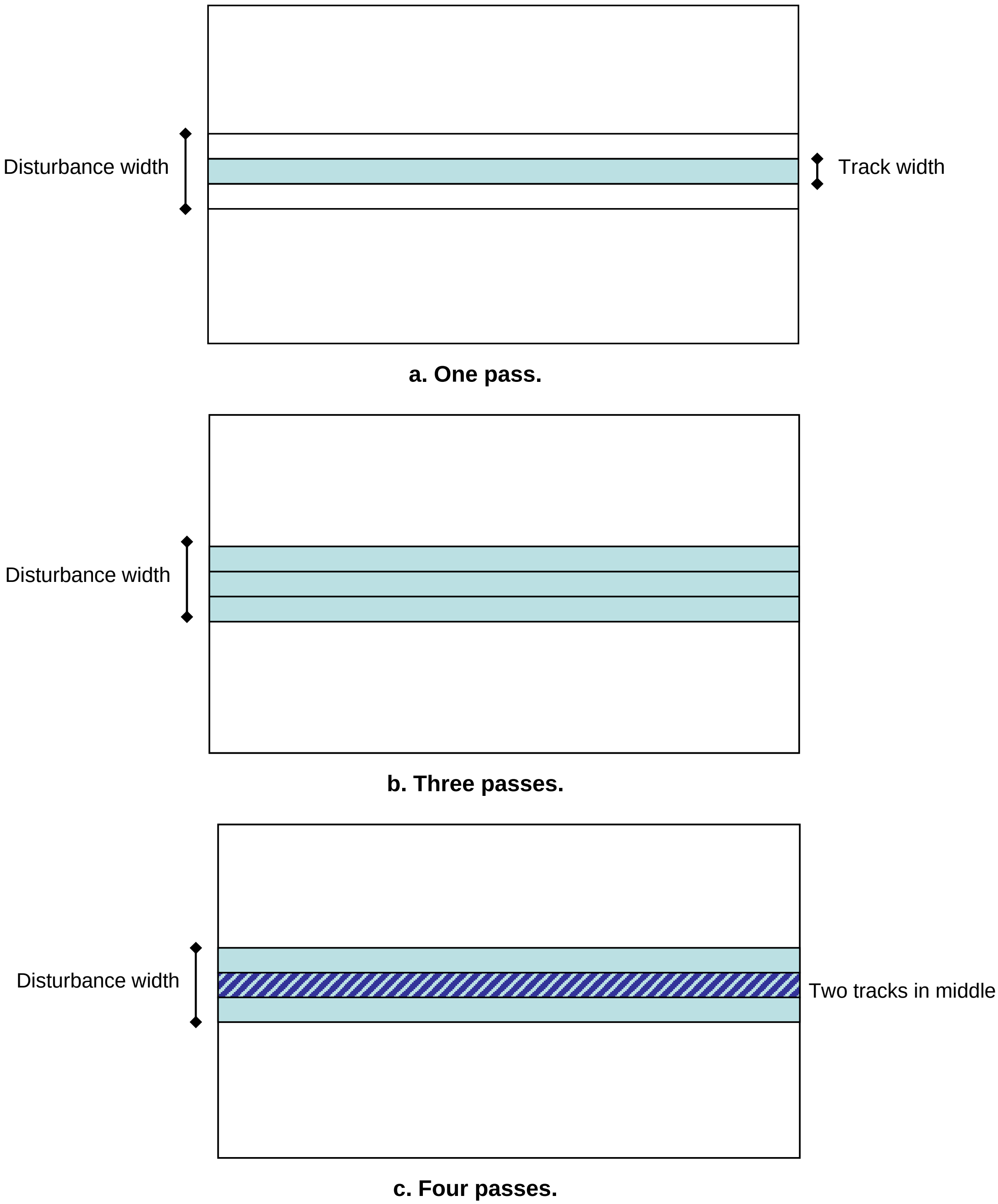

Figure 2. Distribution of tracks on landscape as simulated by trampling disturbance routine.

the maximum pressure the plant can withstand). The maximum amount of pressure the plant can withstand is defined by species at the end of dist_tramp.in. Figure 3 shows how much damage to the plant results from the relative pressures applied.

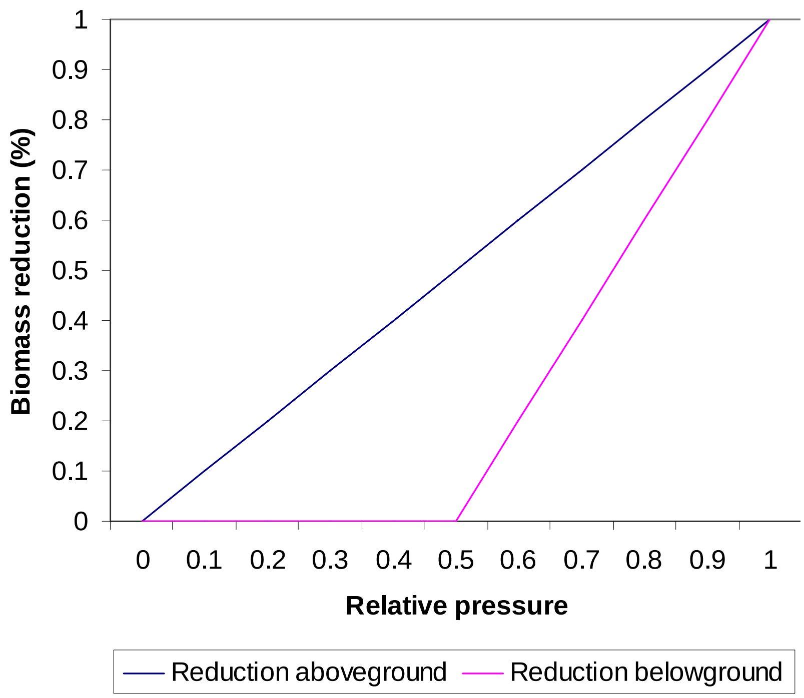

Figure 3. Damage to plant in relation to the pressure exerted on the plant.

If you would like to run the model with more than one plot to simulate a plant population, define the landscape width (lswid in runs.in) and length (lslen in runs.in) such that it includes a number of plots [for the ESA project, the landscape width/length was defined as 5 m for mesquite and 2.5 m for black grama, with the corresponding plot sizes (pltwi and pltlen in runs.in) being 1 m for mesquite and 0.5 m for black grama]. When you use more than one plot, the output in biomass_out.txt is averaged over all plots, and we do not recommend you look at individual plants (the file is too big to process with the macro).

ECOTONE has a lot of input parameters. It is important *not* to get caught up in trying to change all these parameters and understand them completely. In what follows we direct the user to the most important input parameters and explaine how they influence the processes in the model. SOILWAT, the soil water dynamics part of the model, can be learned easily from a Windows stand-alone

version of this model (SLIK-ECO) (http://usda-ars.nmsu.edu/slik-eco/). This version of the model can be downloaded from the web or obtained from USDA-ARS via ftp.* It contains extensive help files and documentation and should be self-explanatory. Once the user has become familiar with SOILWAT, it should be easy to parameterize the soil input files of ECOTONE, since they are exactly the same as the stand-alone version of SOILWAT.

* Debra Peters, USDA-ARS-Jornada Experimental Range, Box 30003, MSC 3 JER, New Mexico State University, Las Cruces, NM 88003.

3 PROCESSES IN ECOTONE

In what follows we present details on the processes in ECOTONE as depicted in Figure 1.

Dispersal

The dispersal function used in ECOTONE was developed in 1989 (Coffin and Lauenroth 1989), mainly with a focus on grass seed dispersal. The dispersal function uses an exponential decay function to calculate the probability that a seed can reach a plot, given its distance from another plot with that species occurring on it. The user input is the maximum seed dispersal distance (SDDIST – species.in). When calculating this distance, the user should take into account the release height and the falling velocity of the seeds, as well as the average wind speed at the study site (Peters 2002). After the probability of seed dispersal to a plot is calculated, it is stochastically determined if the seed reached the plot or not (i.e. seeds will either be available or not for recruitment in this year). If ECOTONE is run with a spatially independent landscape (ltype = 1 – runs.in), the seed availability in the plot is 1 (i.e. seeds are always available).

Establishment

Establishment in ECOTONE is determined stochastically. Each year, a number (between MINREC and MAXREC – species.in) of one-year-old plants can be recruited from a user-defined number of species (between mnrsp and mxrsp – runs.in). The total number of recruits on each plot in each year cannot exceed a user-defined number (mxrec – runs.in). Each species has a probability of recruitment that depends on seed availability (see Dispersal) and a user-defined establishment probability (SDECOF – species.in). The probability of recruitment is normalized to 1.0 for all species eligible for establishment. Species are stochastically chosen for establishment according to their probabilities of establishment until the maximum number of species is drawn (or the maximum number of recruits has been reached, whichever comes first). Each plant recruited is given an initial biomass (corresponding to a one-year-old plant), which is determined as a percentage of the biomass of the full-grown plant [SDFRAT – species.in, the full-grown biomass being input by FULBIOA (above-ground biomass) and FULBIOB (below-ground biomass) – species.in].

Competition

Plant-available water in each soil layer (the soil layer structure of ECOTONE can be defined in soils.in) and each month is simulated using soils and weather data in SOILWAT (transpiration by layer by month). This information is then passed to ECOTONE, and plants compete in ECOTONE for this water. The proportion of water from each soil layer in each month that is distributed to each plant depends on its root surface area in that layer as well as its phenological activity. This proportion is computed based the current root biomass, the biomass:surface ratio (SAREAC for coarse roots, SAREAF for fine roots – species.in), the fine:coarse root biomass ratio (as specified in speclyr.in), and the phenological activity of the plant. The latter is a scaling factor between zero and one that is determined based on the optimal temperature for growth (TMPCOF2 – species.in) and the average temperature of the month [equation 10 in (Peters 2002)]. The relative amount of active root surface area in a given layer for each plant determines the proportion of the water the plant receives, i.e. the competition is symmetric to the active surface area of the roots.

Growth

The plant-available water that each plant receives is summed for the year and is the amount of water the plant can use to grow and maintain its biomass. The amount of biomass that can be grown given the water captured is determined by a biomass conversion factor (WUECNST – species.in). Before growth can occur, the perennial biomass of the plant has to be maintained. The amount of water required to maintain the perennial biomass of the plant corresponds to a fraction (MTNMODF – species.in) of how much water was needed to grow the biomass initially. If the water captured by the plant is less than the water required to maintain its perennial biomass, then clonal plants (CLONTYP = 1 – species.in) can reduce in biomass and other plants are tagged for slow growth. If there is more water available than the plant needs to maintain its tissue, then the plant grows. The new biomass is allocated to different plant compartments according to user-defined ratios: the root:shoot ratio (PRATIO – species.in) determines how much of the new growth is allocated above vs. below ground, the leaf:stem ratio (PARATIO – species.in) determines how much biomass is allocated to annual vs. perennial tissue above ground, and the fine:coarse root ratio (speclyr.in) determines how much biomass is allocated to fine vs. coarse roots.

Root distribution

Before the new growth below ground is allocated to fine and coarse roots, the new biomass is distributed among layers according to relative amount of roots in

each layer. The relative amount of roots per layer is calculated according to a user-defined, species-specific root distribution function at the beginning of each ECOTONE run. The user inputs for this function are the depth of maximum root biomass (RTDEPTH(1) – species.in) and the maximum rooting depth (RTDEPTH(2) - species.in) (Fig. 4). The root distribution is calculated according to a linear function from the soil surface to the depth of maximum root biomass and according to an allometric function from the depth of maximum root biomass [RTDEPTH(1)] to the maximum rooting depth [RTDEPTH(2)] (Sun et al. 1997) (Fig. 4). The user also inputs the relative amount of root biomass at the depth of maximum root biomass [BMAXD(1) – species.in] and the relative amount of root biomass at the maximum rooting depth [BMAXD(2) – species.in].

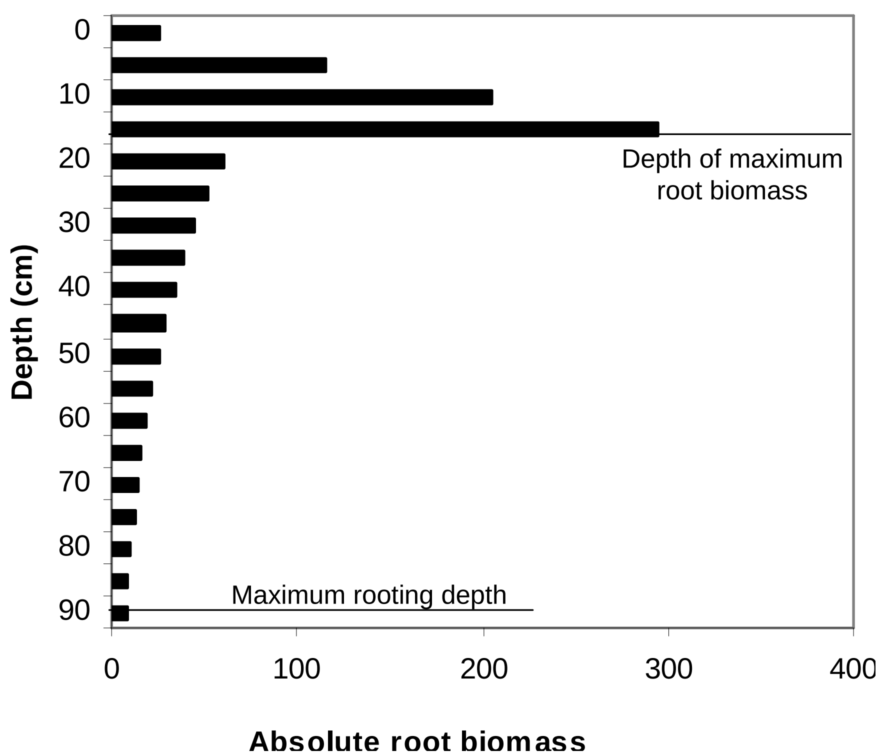

Figure 4. Root distribution of shallow-rooted plants (Sun et al. 1977, Table 7).

Mortality

At the end of each year the entire annual biomass and a certain percentage of the perennial biomass senesces. The percentage of perennial biomass that is lost is defined for each plant compartment: the turnover percentage for coarse roots

(CRTORATE – species.in), the turnover rate for fine roots (FRTORATE – species.in), the turnover percentage of above-ground perennial biomass (LTORATE – species.in), and all of the annual above-ground biomass. The above-ground biomass lost from living plants is added to the litter.

Mortality of plants can have one of four sources: slow growth, size below minimum size, old age, and disturbances (Peters 2002). The mortality due to slow growth occurs after the plant has been growing less than expected [i.e. less than a certain percentage of its size (SLOINC – species.in)] for more than two years. Up to an age corresponding to half of the species' maximum lifespan (AGEMAX – species.in), plants are exempt from mortality due to age. After this age the probability of mortality increases linearly until the maximum age is reached. If the probability is greater than zero, then it is stochastically determined whether a plant dies of old age or not. The above-ground biomass of plants that have died is added to the litter.

Disturbance

There are two kinds of disturbances currently in the model: natural and trampling. The natural disturbances occur stochastically at a user-defined frequency and have a user-defined size (disturbances.in). All plants are killed in natural disturbances, unless they can sprout. The probability of sprouting after disturbance is user defined (VEGGROW – species.in). If the plant sprouts after disturbance, then it regains 50% of its above-ground biomass and reduces its below-ground biomass to 75% of its size before the disturbance occurred. The use of the trampling disturbance routine was described earlier.

Feedback to SOILWAT

Each year a number of plant parameters are passed to SOILWAT to calculate the plant-available water as a function of vegetation characteristics (Fig. 1). When plants have reached their maximum size for the year, the cumulative above-ground biomass (standardized for area) of all plants on a plot is passed to SOILWAT. After mortality and turnover, the amount of litter is recorded, and at the end of the year the root distribution in the plot is averaged between plants of the plot. The latter determines where in the soil the plants take up water.

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